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(6) A NEW UK TELEMETRY SYSTEM FOR GUIDED WEAPON TRIALS

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(10) J. W. King

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SUMMARY

A UK guided weapon telemetry system is being developed for supply by DTGW under the Common User Instrumentation Service. It employs two new techniques. The first is flexible multiplexing which will permit a closer match of system capability to data input sampling requirements than the current 4650 telemetry system provides. The second is pulse code modulation which will permit compatibility with international telemetry standards in addition to its many other advantages.

A computer controlled data processing system offering comparable flexibility on the ground is proposed for RAE Aberporth.

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1 INTRODUCTION

Current UK guided weapon telemetry equipment supplied by DTGW under the Common User Instrumentation Service[1] complies with standards established many years ago. Consequently it is not fully suited to meeting present-day requirements where a greater quantity and variety of data are produced on fewer weapon trials than formerly. Moreover its incompatibility with international standards is becoming increasingly a disadvantage with greater international collaboration of weapon development and increasing need both to fire UK weapons on foreign ranges and to accept foreign weapons on UK ranges.

A new airborne system to revised standards is therefore being developed which employs two techniques new to UK telemetry, namely flexible multiplexing and pulse code modulation (PCM).

Flexible multiplexing, which relies on the use of electrically addressable multiplexing switches and a programmable read-only memory, will permit a much wider choice of both data input channel capacity and sampling rates as well as the ability to specify changes to the sampling programme between weapon trials. For the more complex tasks, for which application of this new technique is primarily intended, the improved flexibility will be accompanied by a system reduction in both physical size and production cost.

Telemetry standards generally adopted by NATO, except currently the UK, are formulated by the American Inter-Range Instrumentation Group (IRIG)[2]. In accordance with the conclusions of a recent study[3] by Instrumentation and Trials Department, RAE on the provision of a UK telemetry service based on the IRIG standards, compatible PCM is being introduced at the same time as flexible multiplexing. Both techniques are embodied in a single unit being developed under a DTGW contract by EMI Electronics Ltd generally in accordance with proposals ensuing from a feasibility study[4]. With an existing radio frequency (RF) transmitter this will form a complete airborne PCM telemetry system.

As a further benefit of compliance with international standards, units are commercially available from which a system can be assembled for processing received data at the Range. Since processing can be under computer control a comprehensive range of facilities can be offered and the flexibility provided by the airborne equipment can be matched by corresponding flexibility on the ground.

In addition to a discussion of the new airborne techniques this Memorandum includes a brief description of the ground system proposed for installation at RAE Aberporth.

2 CURRENT UK ADVANCED TELEMETRY SYSTEM

The benefits of the new developments can be more easily understood after an initial consideration of the current UK high data rate telemetry system. Called 4650 Variant II this is an analogue system, shown in its basic form schematically in Fig 1. Sixteen input channels, including two devoted to synchronization and calibration, are sampled uniformly in rotation by a time division multiplexer to produce a train of equally spaced pulses each of voltage proportional to the amplitude of the input being sampled. The resulting pulse amplitude modulation (PAM) data stream, at a fixed rate of 64 k sample/s, then frequency modulates (FM) an RF transmitter to produce a PAM/FM signal which is radiated by the vehicle aerials.

Input terminals of the 16 channel multiplexer can be driven from available 24 or 48 channel multiplexers which can themselves be fed from further similar multiplexers so that the total input channel capacity can be increased and a range of channel sampling rates provided. Intermediate sampling rates can be obtained by symmetrical wire linking of multiplexer input terminals and hence allocation to a single input channel, naturally at the expense of total input channel capacity. Such techniques for increasing the range of channel sampling rates are normally called subcommutation and supercommutation, terms hung over from the days of motor driven rotary switches and having no place in modern thinking. Although multiplexers for 4650 Variant II now use semiconductor switches these are still operated in the same uniform sequence by an electronic counter owing to the need to adhere to established telemetry standards[5].

For meeting present-day requirements the system has many disadvantages. Matching of input channel capacity and sampling rate requirements to telemetry system capability is often far from ideal and compromises have to be accepted. System hardware can be bulky and expensive with the need for many individual multiplexers, each with its built-in power supply and calibration and synchronization facilities. Since the equipment is hardwired the input channel sampling sequence, which includes the setting of input sampling rates, must be known months in advance of use and cannot therefore usually be modified between weapon trials.

When the principles of flexible multiplexing have been described in the next section it will be shown how use of the new technique can remove these disadvantages.

Further disadvantages of 4650 Variant II result from its being an analogue system. For example, the already high size and cost penalties are increased by

the need, becoming more frequent, for twice the total sampling rate available and hence for two telemetry systems simultaneously radiating at different radio frequencies. Also, since the transmitted data structure does not conform even to analogue international standards, special Range ground equipment is required which, moreover, is unable to process data received from foreign airborne telemetry systems.

It will be shown later how these further disadvantages can be overcome by use of PCM.

3 FLEXIBLE MULTIPLEXER

The flexible multiplexer is shown schematically in Fig 2. It relies on the use of semiconductor switches which can be addressed in any desired sequence in accordance with instructions stored in a programmable read-only memory (PROM) and output under control at a rate determined by an adjustable clock frequency.

It is again a time division multiplexer and the output serial data stream comprises a series of repeated major frames, or complete sample sequences containing one sample of each data input sampled at the lowest rate. It follows from the limits defined by the IRIG PCM standard, as shown in Fig 3, that a major frame can contain more than 0.5×10^6 data channel time intervals, each occupied by either a data sample or a part of a synchronization pattern. To store the sequence of corresponding channel switch addresses for reproduction by simple memory cycling would require storage of a similar number of words, say of 9 bits for 512 input channels, impossible in the space of a small guided weapon instrumentation package. In foreign commercial products this difficulty has to some extent been overcome by organization of the memory such that it simulates banks of rotary switches but clearly this method still suffers from many of the disadvantages which are desired to be removed.

The method of memory organization and control being adopted in the unit now being developed, known as the programmable multiplexer encoder type PME30, is a unique one invented[6,7] within Instrumentation and Trials Department, RAE. It permits extreme flexibility with use of a minimum amount of memory capacity. Its principle is best explained by examination of a simple example, illustrated in Fig 4. In this example eight input channels, labelled a to h , are sampled at one of three binary-related rates, 1, 2 and 4. At each rate channels are sampled in order, with priority being given to sampling at the highest rate first and with the sequence being reset periodically, in the example every five

channel time intervals, easily calculated from knowledge of the number of channels at each rate.

Thus, channels a, b and c at the highest rate are sampled first. Since there are no more channels at this rate channels d and e at the next rate are sampled, after which there is a reset. Channels a, b and c are again sampled and then channel f at rate 2. Since there are then no more channels at this rate channel g at the next rate is sampled. Following another reset channels a, b, c, d and e are again sampled and then channels a, b, c, f and finally the last channel at the lowest rate, h.

The amount of memory capacity required with this method is extremely small. Two words are required to define the start and stop numbers of the number sequence at each rate, that is, a and c, d and f, and g and h in the example. One word is required to define the reset period, that is, five channel time intervals in the example. And words equal in number to the input channel capacity are required to translate the sequential channel numbers, a to h in the example, to the addresses of the appropriate input channel switches. For example, as proposed for the PME30, for up to 512 inputs sampled at any of 12 binary-related relative rates, a memory capacity of 537 words of 9 bits is required, which can be contained on four integrated circuit chips.

Compared with that in the 4650 Variant II system the greater flexibility of the new method of multiplexing is easily seen. All multiplexing switches are similar and independent and any number can be switched in any order and at any binary related rate, the only limitations being the design maxima and, if required, compliance of the sample sequence with the major frame structure defined by any chosen standard, for example the IRIG PCM standard illustrated in Fig 3.

For subsequent demultiplexing, certain channel time intervals must be devoted to synchronization. But even with this small constraint the method of memory organization and control described permits simple programming and hence determination of the necessary sample sequence to meet a given requirement, thus contrasting sharply with the lengthy task of choosing the best selection of rigidly defined multiplexers of the 4650 Variant II system.

4 PCM ENCODER

Fig 5 shows how a PCM encoder is added to the flexible multiplexer and thus, with an FM transmitter, forms a complete airborne PCM/FM telemetry system.

An analogue to digital converter (ADC) digitizing the analogue data samples output by the multiplexer is preceded by a sample and hold circuit to reduce sampling aperture time when the data rate is high. In addition to analogue inputs either serial or parallel digital inputs are shown which are sampled under programme control and inserted into the PCM data stream by the word selector when a flag indicates that a digital channel is being sampled. The word selector also inserts minor frame and subframe synchronization words and serializes the data stream before conversion from NRZ-L (non return to zero-level) into an alternative digital code if required.

In addition to permitting compatibility with international standards there are other advantages of PCM compared with the analogue modulation of the 4650 Variant II system. Some of these are as follows.

Total system accuracy, measured between the input terminals of the airborne equipment and the output terminals on the ground, is higher with PCM. For an adequate RF signal strength the expected accuracy of 0.4 per cent rms of full scale range is limited only by analogue processing before and during digital conversion and remains unchanged by any subsequent processing. Just as important is the easier control and maintenance of this accuracy. The 4650 Variant II system accuracy, usually accepted as about 1 per cent rms of full scale range, is achieved with difficulty and is very dependent on operator skill.

For the same data rate as 4650 Variant II a PCM system has a greater transmission range. This advantage has particular importance where propagation conditions are unfavourable, as for example on trials of sea skimming weapons, where the range improvement factor is between 1.4 and 2.

For a given RF bandwidth the total sampling rate of a PCM system can be about four times higher than that of 4650 Variant II. Thus requirements currently demanding use of two telemetry equipments radiating at different radio frequencies in one weapon will be met by use of only one PCM system in the future. This advantage is also important since by 1981 guided weapon telemetry transmission in the UK has to move from the UHF band to L band where there will be greater necessity to keep within the frequency limits allocated.

Digital data inputs, derived from either digital transducers or bi-level data sources, are readily accommodated by a PCM system but are not efficiently handled by an analogue system.

On the ground, with the recovered data being in digital form, demultiplexing, data limit checking and scaling, and other data processing can be readily

done either by computer or under computer control, thus preserving total system operational flexibility.

5 PROGRAMMABLE MULTIPLEXER ENCODER TYPE PME30

As was stated in section 3 the flexibility of a practical electrically programmable multiplexer is limited primarily only by the maxima of the principal design parameters. In the PME30 these are 512 input channels, 12 binary-related relative sampling rates, equivalent to a sampling rate ratio of 2048 to 1, and a total sampling rate between 1 k and 128 k sample/s.

Considerable flexibility is also provided by the PCM encoder. Digital word length, parity, type of subframe synchronization, and output code are all variable.

Fig 6 shows the proposed mechanical configuration of the modules of which the PME30 is composed. The gate module has two versions, containing addressable switches for multiplexing either 64 analogue or eight digital inputs. Up to eight gate modules can be accommodated. The PCM module contains the sample and hold, ADC, synchronization word generator, word selector, and code converter. Another three modules are required for the programmable memory, its control, and the system power supply.

6 RANGE GROUND EQUIPMENT

The high operational flexibility of the airborne equipment necessitates comparable flexibility for real-time monitoring and post-trial quick-look on the ground. The high data rates to be handled preclude computer demultiplexing in real time. Hardware demultiplexing under control of a small computer is therefore proposed for RAE Aberporth as shown schematically in Fig 7.

The equipment basically comprises bit, minor frame, and subframe synchronizers for derivation of appropriate timing pulses, and a programmable word selector for extraction of selected channels for output in either analogue or digital form, for example for hard-copy production or binary or decimal display. The timing pulses are input to the computer via an interface and bus. In return, under command of the operator through his input/output typewriter, set-up instructions are sent via another bus to all appropriate units, which also include a manual override facility. The computer can also be used for data limit checking and conversion to engineering units, and other simple processing tasks.

In addition to permitting rapid demultiplexing reconfiguration between tasks, system control by computer also introduces the possibility of time-shared

remote control and display at trial sponsors' missile preparation buildings, thus obviating a multitude of costly independent test sets about the Range.

New equipment in the Aberporth Data Centre comprises only bit and minor frame synchronizers, enabling reproduced data to be converted by the existing computer and re-recorded in computer compatible form.

The proposed Range ground equipment can process any telemetered data conforming in structure to the IRIG PCM standard, from whatever its source.

7 CONCLUSIONS

It has been shown how the use of electrically addressable multiplexing switches and a programmable read-only memory will enable a new UK guided weapon telemetry system currently under development to provide a much wider choice of data input channel capacity and sampling rates than is available with the 4650 Variant II system. Inclusion of PCM encoding will provide additional advantages including compatibility with international standards, higher accuracy, greater transmission range, and higher total sampling rate, as well as more efficient handling of digital data inputs.

Computer controlled data processing equipment proposed for RAE Aberporth will enable total system flexibility to be preserved and will handle any telemetered data conforming in structure to the IRIG PCM standard, from whatever its source.

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Documents quoted are not necessarily available to members of the public or to commercial organizations.

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* later designated PME30

** Plessey Company Ltd

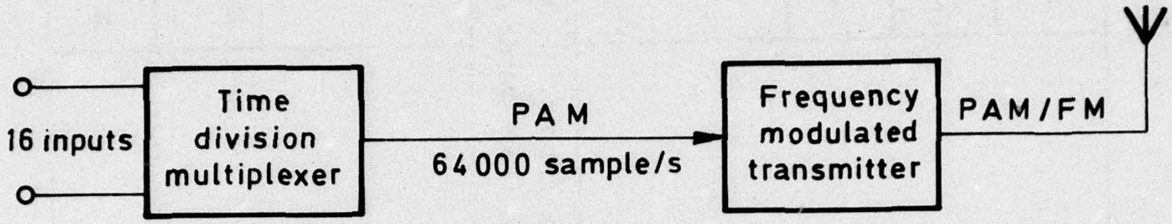

Fig.1 Basic 4650 variant II telemetry system

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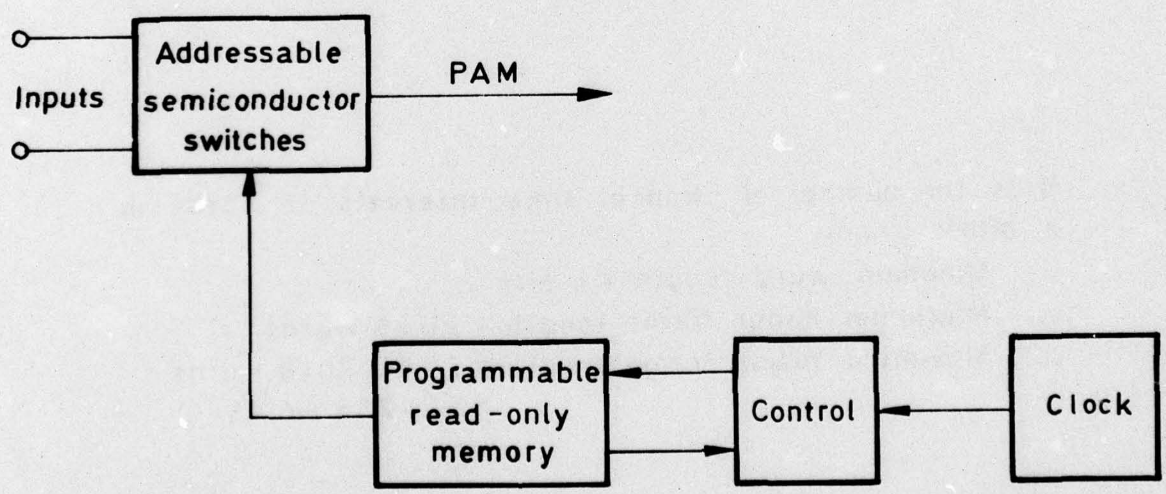
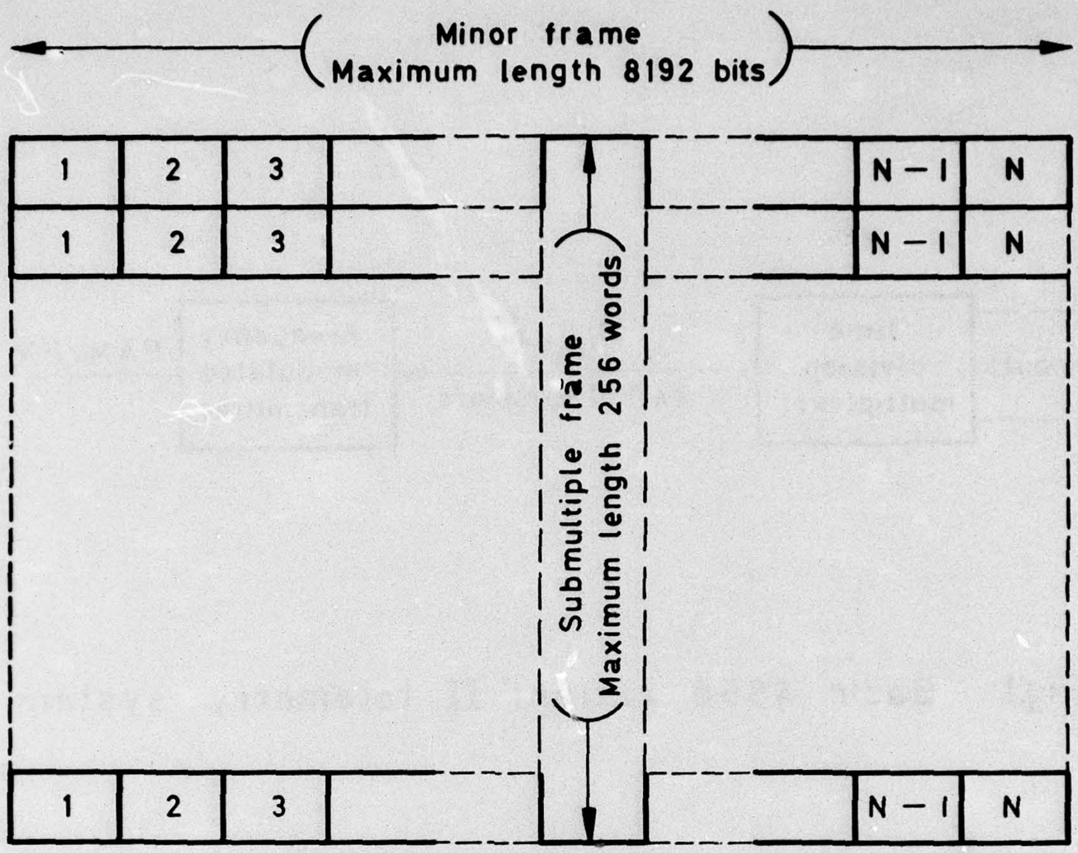


Fig. 2 Flexible multiplexer

Fig. 3



N is the number of channel time intervals or words in a minor frame.

Minimum word length = 4 bits

∴ Maximum minor frame length = 2048 words

∴ Maximum major frame length = 256 x 2048 words

= 524288 words

Fig. 3 IRIG PCM major frame structure

Relative sampling rate	Channel time interval number																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
4	a	b	c			a	b	c			a	b	c			a	b	c		
2				d	e				f					d	e				f	
1										g										h

Fig. 4 Flexible multiplexer example

Fig.5

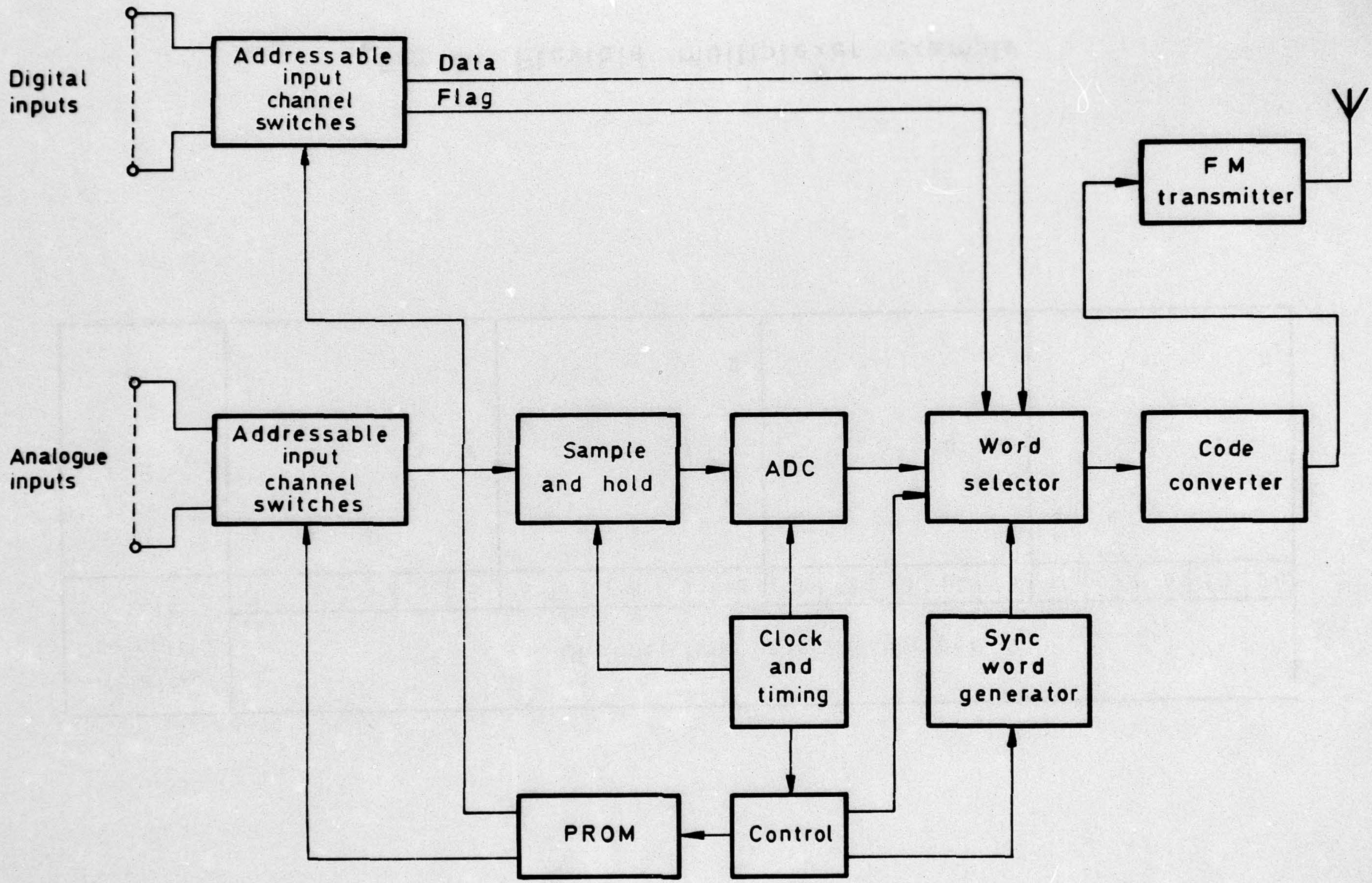


Fig. 5 Airborne PCM / FM telemetry system

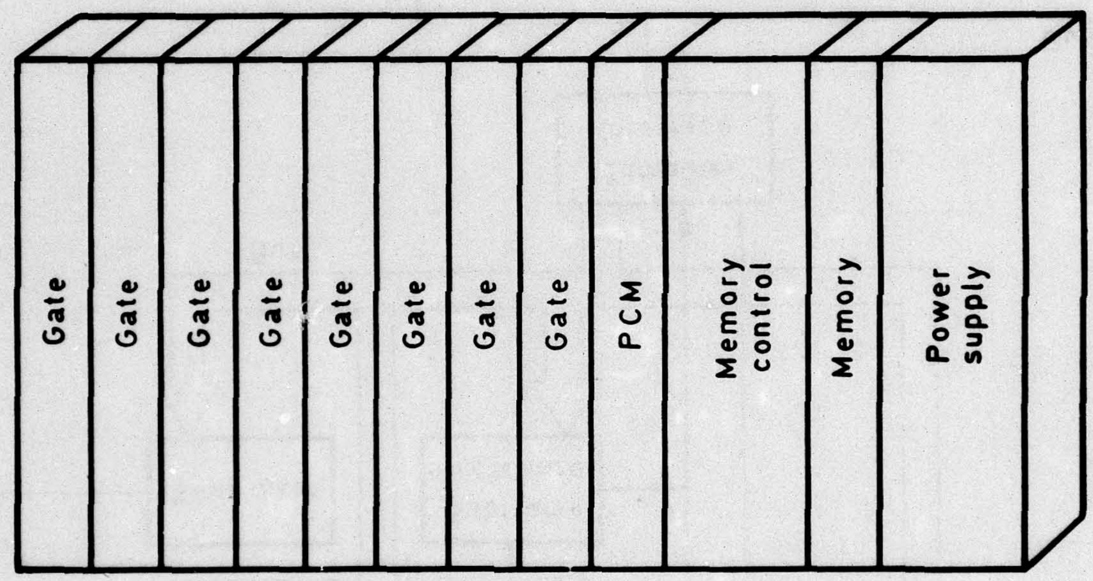


Fig. 6 PME 30 module configuration

Fig.7

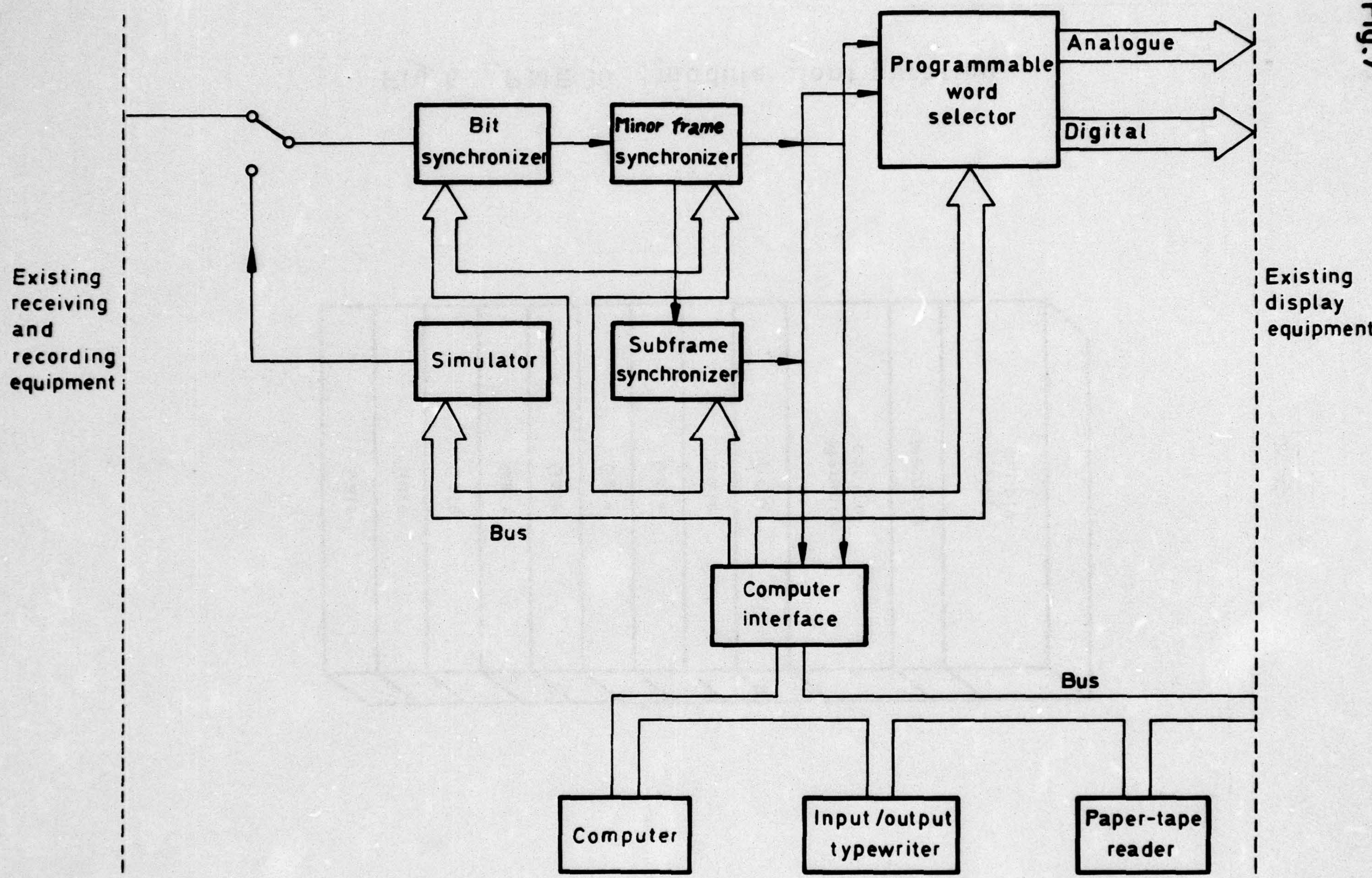


Fig. 7 PCM system ground equipment

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17. Abstract

A UK guided weapon telemetry system is being developed for supply by DTGW under the Common User Instrumentation Service. It employs two new techniques. The first is flexible multiplexing which will permit a closer match of system capability to data input sampling requirements than the current 4650 telemetry system provides. The second is pulse code modulation which will permit compatibility with international telemetry standards in addition to its many other advantages.

A computer controlled data processing system offering comparable flexibility on the ground is proposed for RAE Aberporth.

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